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AD NUMBER
AD835842
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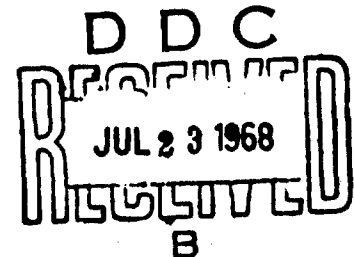
AD 835842

TRANSLATION NO. 1663

~~REDACTED~~  
DATE: 18 April 1966

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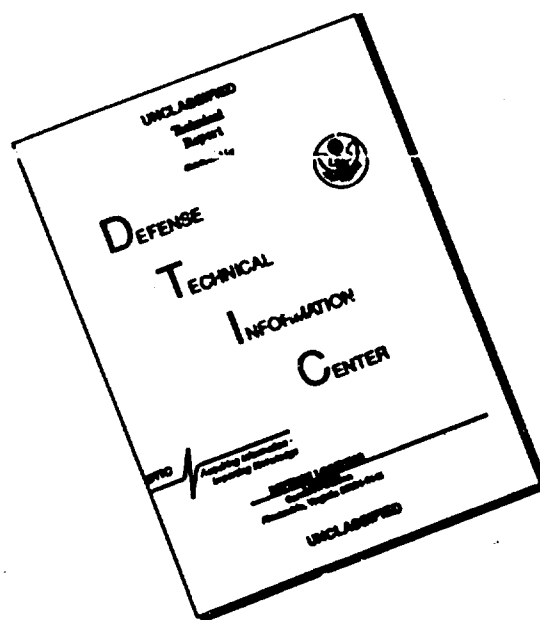
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## STRIPED WITHERING OF RICE LEAVES AND ITS PREVENTION

Nogyo oyobi Engei  
(Agriculture and Horti-  
culture) 30 (6): pp. 823-  
26, 1955.

YAMADA, Sai

Colloquially the striped withering of rice leaves is called Yureibyo ["ghost sickness."]. It began to occur around 1847 in Gumma, Tochigi and Nagano prefectures and in 1926 and 1929 caused great devastation of crops in the Kanto area beginning with Tochigi prefecture and in Nagano prefecture. Research on the disease was carried out during this period, but its cause remained a mystery, so the late Dr. Kuribayashi conducted research at the Nagano Agricultural Testing Station and determined in 1931 that it was a type of virus disease caused by the intermediation of the Hiretobiunka (Delphacodes striatella FALLÉN). Amano also reported on the plants on which this disease is parasitic and the hibernation conditions of the above insect. In 1939 Dr. Kawaai studied the disease in situ and proved the existence of x bodies in the cells of leaves suffering from this disease and it was confirmed that this was a virus disease.

It is reported afterwards that this disease was widespread in the Kanto area in 1950 and 1954. Apparently it had long been prevalent in Okayama prefecture, but became more widespread after about 1935 and local damage was observed in 1938. Afterwards, in 1949 and 1950, damage was greatest in the grain storage areas of Fujita and Kojo in Kashima-gun, Okayama prefecture and there were some rice paddies where no crops were obtained at all. The fact that damage was greatest in 1950 and has been declining gradually since then is related to a decrease in the areas of direct planting of wet rice plants. The yearly areas of direct planting of wet rice plants in the village of Kojo (paddy area, 1,250 cho) are as follows:

1948.....	320 cho
1949.....	300 cho
1950.....	230 cho
1951.....	20 cho

[One cho = 2.45 acres]

The area was reduced in 1952, 1953 to only a few cho. This method of cultivation became popular as a means of counteracting the lack of irrigation water in the rice planting season and the lack of a labor force during and after the war. Apparently the reason for the sharp decrease in the cultivated area since 1951 is due to proliferation of the disease in the previous year and an increase in the labor force perform household.

Due to the above state of affairs, tests to eliminate this disease were needed, so research was begun in 1951. There was very limited previous material on the disease and no knowledge of the method of transmission of the virus, so this author felt that in order to work out a complete method of eliminating the disease, tests to determine the relationship between the occurrence of the disease and the virus carrying insect, ~~were of first~~ importance. Tests are under way at the present time and the course of transmission of the virus has been more or less determined. For this reason the author, together with Shioda and Yamamoto published in Vol. 52 of the Occasional Papers of the Okayama Prefectural Agricultural Testing Station, Report No. 1 on the relationship between occurrence of the disease and contamination via the Delphacodes striatella ~~PALLIS~~, and Report No. 2 on the occurrence and elimination of the disease. Moreover, technical officer Shinkai of the Agricultural Research Office conducted research on virus infection of this disease and achieved approximately the same results as the author, so I decided to describe the transmission of the virus of this disease and methods of prevention and elimination, ~~contrasting my~~ results with those of Shinkai.

## 2. Disease Characteristics

In early occurrence, the disease appears at the end of the nursery period (for rice plants). The upper leaves turn yellow green and yellow white or a white, splashed pattern of spots appear, running parallel with the veins of the leaf. These plants, or inflected plants lacking such symptoms were transplanted in the paddies, and those which became infected soon after transplanting show practically no abnormalities on the lower leaves. The young, i.e. the "heart" or center, leaf goes along the center vein, is firmly wrapped upward the edges and is twisted. It is usually bent like a bow and hangs with its tip down. This symptom is unusual and is the probable origin of the colloquial term yureibyo ["ghost sickness."] The young unfolding leaf and the sheath display yellow white spotted stripes in several places as described above. As the "spotted withering leaf disease" [literal translation of goma bakana bwo] progresses, the spots become much larger than usual. Around the hottest part of summer most of the plants, including the stumps wither and die, and only a few stumps are left standing.

When the disease occurs in the final stage of the plant's life (i.e. just prior to harvesting) the tillers become uneven, the leaves have a pale color and either yellowish white or greenish white spots appear on the

shiyo ["stopped leaf"] or the upper leaves, or there is a tendency for one side of the leaves to change color in the same way and become slightly curled. However, the "stopped leaves" are not twisted.

During the earing period, one can observe, as regards diseased stems, those stems on which earing takes place, those in which there is no emergence and those with partial emergence. In any case, an unusual color develops on the "stopped leaves" and two or three leaves below it. The ears are all irregular in shape. The head is imperfect or merely forms a spike. It is first pale yellow and then white and a few grains ripen, but no perfect or complete mature rice plant develops. It is easy to confuse the above with karabae [a condition in which no fruit develops in the ears] or damage from sparrows eating the ears, but the disease can be determined through examination of the leaves. Frequently black fungus appears on the surface of the head.

Generally, in the case of outbreak of the disease shortly after planting in the field, the same tillers may be totally affected by the disease. When the disease breaks out shortly before harvesting part of the tiller is frequently invaded. Dwarfing and etiolation are diseases similar to this. The former is a virus disease brought by the Tsumaguro yokobai [insect]. In this case there are numerous tillers but they are stunted in growth, the leaves are dark green and minute white, solid or dotted lines appear on the leaves. The latter occurs through water infection from the bacterium called Phytophthora macrospora. The seedlings become completely yellow green, and in the field yellow white circles or spots develop on the leaves. Even if earing takes place the heads fail to emerge, which is similar to the striped withering disease. The disease under consideration can be distinguished by the fact that an unusual bluish white color appears and the young "heart" leaf becomes curled and twisted, withers and dies early.

### 3. Cause of Disease

At first, research on the disease was based on the theory that it was caused by a parasitic bacterium, then it was explained as due to the inemukugemushi ["insect which peels the skin off rice plants"], so for a long time the cause of the disease went undiscovered. Finally, as explained above, it was found in 1931 to be a virus disease due to the intermediation of the Delphacodes striatella FALLÉN.

The authors conducted experiments, with the above in view, to study the eating habits and toxicity retention (retention of virus) of the Delphacodes striatella FALLÉN (hereafter called "leaf hopper") in order to determine the relationship of the method of spreading the disease virus to the outbreak of the disease. Of course, Dr. Kuribayashi's results were

investigated and clarified. The tests were conducted using a method to detect the outbreak of disease in which young rice seedlings were inserted and cultivated in test tubes. Leaf hoppers were individually cultivated. The seedlings were transplanted to boxes with screen covers.

When the degree of retention of virus in the leaf hoppers, collected from areas prevalent in the disease and areas where the disease was relatively rare was investigated, it was found in each case to be about 5% which is relatively small, and the insects had no capability to transmit the virus. This is believed to be due to the fact that there is a difference in the carrying capacity of individuals and groups and those associated with the disease are restricted in numbers. The areas of proliferation are the habitat of a greater population density of leaf hoppers, the disease rate is high and the population density of the insect apparently determines the outbreak of the disease.

More than ten minutes, or rarely, three to five minutes of attack by a virus-carrying leaf hopper is required to cause infection in healthy seedlings. Symptoms usually occur after a latent period of 7 to 20 days. Kuribayashi reports 12 to 46 days, but this period is believed to vary according to the cultivation time of the rice plant. Leaf hoppers with an affinity for the virus become carriers of the virus when they suck the sap of a diseased rice plant for more than 30 minutes, but for 7 to 14 days after being attacked by the insect, the plant manifests no disease. This is called the "latency period within the insect" and apparently during this time the pathogenic virus proliferates to the degree at which it can be transmitted. However, when such an insect sucks the juices from a diseased plant just before laying eggs, virus-carrying insects were found among the larvae which were laid and hatched 6-14 days later. It was found that larvae born from those insects which carried the virus just before laying eggs, contained the virus from the day they were hatched and possess the capability of spreading the disease. The latency period inside the insect's body is very short.

As explained previously, not all leaf hoppers retain the virus. They are differentiated into active and inactive races. Descendants of active x active appear to be those which contain the greatest toxicity (virus). At most this is 50%. The least number is found with inactive x inactive, while both the active x inactive and inactive x active races occupy a central position. No difference is observed between male and female with respect to acquisition of the virus. Moreover, larvae from the first to the fifth instar showed no difference in retention of virus. However, judging from the fact that the larvae which carry the virus carry it until their death and become afflicted, and have continued to carry the virus down to the tenth generation now under study, it is believed that the descendants of virus carriers, as long as they continue, will produce other virus carriers. However, those descendants will probably not continue for long under natural conditions due to natural enemies, etc. If they continued for a long time the density of virus-carrying insects should increase.

When the female leaf hoppers are virus carriers, almost all offspring are also carriers, regardless of whether the males crossed with them carry it or not. On the other hand, retention of the virus among males is unrelated to retention of the virus in offspring, i.e. virus carrying female x virus carrying male

virus carrying female x virus free male	virus carrying
virus free female x virus carrying male	virus carrying
virus free female x virus free male	virus free
	virus free

This phenomenon is called "infection by egg" and is extremely rare. Professor Fukushi empirically proved this for the first time for the Tsumaguro yokobai which is an insect acting as a medium for the Ineshukubyo "rice plant dwarfing disease" virus. After him, only Black in the U.S. has demonstrated this phenomenon in the virus disease called club leaf in clover. The author and Mr. Shinkai discovered the same phenomenon last year in the leaf hopper which is the medium for the disease under study in this report and simultaneously presented an oral report on it at academic meetings. Even if the virus carrying female does not partake even once of the juice of a disease rice plant, the virus of the disease will continue to be transferred through the eggs for all generations.

Problems which are still unsolved and require further research include (1) whether the virus carrying leaf hoppers which fly from nursery to nursery have hibernated or carry the virus because they sucked the juice of diseased grasses and (2) the relationship between the period of transmission of the disease and the vegetation period of the rice plant.

#### 4. Methods of Eradication

(1) Habitat of the Leaf Hopper. In eliminating this disease, total destruction of the virus carrying insect is most urgent. It is necessary to study the hibernation and hibernation areas of the insect and the conditions in the habitat in the field. The author for three years starting in 1951 investigated the habitat of this insect by netting and collecting the insect in wheat fields and their vicinity, rice nursery beds and rice in the rice paddies the "target areas" were the areas of Fujita-mura in Kashima-gun where the disease is widespread and areas where it occurs infrequently (the northern fields of Okayama City). Results are shown in Table 1.

The hibernation conditions of this insect in the areas where the disease occurs have been studied in detail by Dr. Kuribayashi and Mr. Amano, and this author has achieved almost identical results. That is, he collected insects which hibernated in the larval state in one part of the wheat fields at the beginning of February, the mounds of grass next to the ditches, along the edges of the rice paddies and on river banks. In the last part of March, they emerge and become imagoes. Then they move to the rice nursery and increase rapidly in the first part of June after the wheat harvest,

reaching maximum density in the middle of June. After that they rapidly decrease. The population density is greater in the areas where the disease is most prevalent and a few of them were caught during the period in the rice paddies.

The results of investigating the retention of the virus in the hibernating insects are, as described above, around 5% and as the population of the insect increases, the opportunity of transmission of the disease degree is believed to be greater.

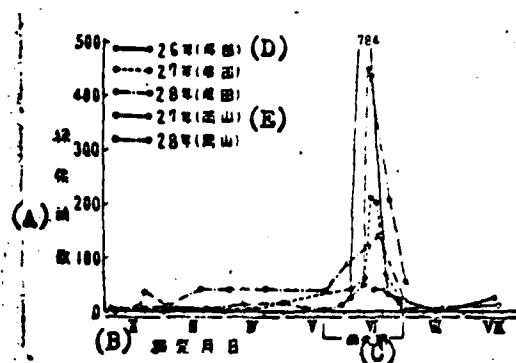


Figure 1: Population density of leaf hopper during and close to the nursery bed stage and rice.

A - number collected; B - Date of investigation;

C - Nursery bed; D - Fujita; E - Okayama; 26 = 1951, 27 = 1952, 28 = 1953

Also by discovering the population density of this insect during the nursery stage, such information can become data for predicting the extent of proliferation of the disease during a particular year. This can be considered from the article by Dr. Hashioka in which he states that a large outbreak of this disease was predicted from the fact that this insect occurred with unusually great density in the nurseries in 1950 when the disease was very widespread.

(2) Methods of Elimination: As a means of controlling the disease, tests were conducted to study the cultivation methods for each type of rice plant in the seeding and planting periods, and to study the relationship of the outbreak of the disease and control of the carrier insect by spreading insecticides. It was found that the leaf hopper shows a great difference in population density according to the year, area and location of test field. Consequently, since outbreak of the disease is not uniform considerable errors were observed depending on the location of the testing areas and accurate results were not obtained. Below, methods of controlling this disease are given with reference to the results achieved in each area.

(a) Selection of disease resistant varieties. The authors tested 20 different varieties through ordinary planting and direct planting, but were unable to note any difference in the degree of contraction of the disease. However, professors Kuribayashi and Igata of the agricultural test stations in Gurma and Kanagawa report that there is a great difference in the extent of contraction of the disease according to the type of rice plant, so it is desirable to select and plant disease-resistant varieties in each area.

(b) Eradication of the leaf hopper. It goes without saying that the first principle of controlling this disease is to eliminate the insect which carries the disease virus. Dr. Kuribayashi was the first to report on methods of exterminating the carrier insects, and after him many others have written in similar fashion, but there are very few results on actual tests to eliminate the carrier insects by means of insecticides. The tests previously conducted by the author were somewhat poorly organized but he achieved some success in controlling the disease by spreading insecticides. The result are as shown in Table 1. There is a great difference between the seedlings in field and those brought back to the test station. The differences in the outbreak of the disease are believed to be due to the place of selection of seedlings.

Table 1: Results of Tests in Spreading Insecticides in Nurseries Seedlings

Classification	1951		1952
BHC Water Solution 0.02% applied 4 times	2.5%	2.4%	17.8%
BHC Powder 1% applied 4 times	1.5%	-	13.7%
[Horidol] Emulsion x 1000 applied 4 times	-	-	9.8%
Not applied	6.7%	42.9%	32.2%

Remarks: Type tested....Asahi. Method.....After applying a specific amount of insecticide during the seedling period from the beginning to the end of June, they were transplanted in the paddy and the occurrence of disease investigated.

\*.....Results of investigating after taking seedlings from the test area to the laboratory and planting each seedling separately from the other.

However, even in the above tests, it cannot be said that the disease was completely controlled. This is due to the fact that the insect has a long proliferation period and can catch and spread the virus in a short

period of time, so it is difficult to exterminate the insect completely. Also, in the same way as with other viruses, when indications are that the disease can be spread quickly by insertion of the virus carrying insect's proboscis into the rice plant, total prevention is difficult unless the insecticide is completely effective against the insect. The effectiveness of the application of the insecticide can be seen from the fact that farmers in the two villages of Fujita and Kojo, where the disease is prevalent studied the prevention tests of the author in the area in 1951 and 1952 and applied BHC insecticide powder several times to the seedlings, after which the outbreak of disease decreased rapidly. These areas in recent years have seen the emergence of the three-brooded rice borer. The fact that as a means of exterminating these, four applications of 200 x of 20% DDT emulsion (0.01% solution) and 1000 - 2000 x parathion emulsion from the beginning to the end of June was successful means that we can say that this method "killed two birds with one stone" because the leaf hopper was eradicated and simultaneously the disease was prevented.

It is believed that there is a marked difference in the period for application of insecticides to seedlings as a disease preventative, the method depending on the area and type of seedling. In the southern region of this prefecture where the disease is prevalent, the first application of insecticide to the seedlings was made in the first part of June immediately after the wheat harvest. It is apparently advisable to apply the insecticide every other week after that three or four times. In the Kanto area it is said that the spread of the virus is great in the paddies in the initial period, so it is necessary in those areas to again apply the insecticide in the paddies. Also, since the leaf hopper very frequently hibernates in the larval stage in the ditches near the paddies and in piles of grass near the edge of the paddies, it would probably be helpful to burn those weeds in the spring and kill the insects before they have a chance to come in contact with the seedlings.

Table 2

Classification	No. of Seedlings Studied	No. of Diseased Seedlings	Rate of Disease Contraction
a. Nursery beds observed to be almost free of disease	489	8	1.6%
b. Nursery beds with average outbreak of disease	350	171	48.9%
c. Nursery beds in which disease was widespread	627	516	81.3%

Table 3

Classification	No. of Seedlings Planted	Rate of Disease Occurrence
a. Healthy seedlings in nursery beds which were observed to be almost free of disease.	105	9.7%
b. Healthy seedlings in nursery beds which had average outbreak of disease.	105	21.0%
c. Healthy seedlings in beds where disease was widespread	63	61.9%

(c) Caution in planting: The outbreak of disease is greater, the earlier the planting season. Generally, thinly spread seedlings suffer more than densely planted areas since the disease is more prevalent, even in the same short bed among seedlings on the perimeter rather than among those in the center. Outer seedlings in areas where the disease has occurred should not be transplanted.

Also, there is a tendency for prevalence of the disease in the special planting method in which each seedling is planted separately when cultivating thick plants with many tillers. In this case, the symptoms of the disease occur throughout the plants, so if one of them becomes afflicted a critical condition arises, hence in areas where the disease is prevalent it is necessary to consider arranging the seedlings so that more than 2 are planted together.

(d) Elimination of weeds and rice plant stocks afflicted by the disease: Table 2 presents the results of investigation of the rate of affliction of seed beds (variety: Asahi) for seedlings in Fujita-mura, Kashima-gun in 1950 when there was a large outbreak of the disease. Table 3 shows the results of investigation the pathological conditions of seedlings planted individually when were believed to be healthy and which were separated from the diseased seedlings in each area. According to the table, when there is considerable occurrence of the disease in the seedlings, it was found that even if seedlings are selected from them which are thought to be free of disease, and planted, they become infected with the virus and the disease spreads after transplanting to the paddies. This means that one must be careful to note that the rate of occurrence is proportional to the rate of contraction of the disease in the seedbeds. When the disease is detected at the end of the seed bed stage, as many diseased seedlings as possible should be eliminated and the remaining seedlings should be transplanted in as large groups as possible. In the case of widespread disease,

the seedlings from the diseased bed should not be planted. Instead, planting of other seedlings is desirable.

In the initial paddy stage, first previously prepared seedlings should be additionally planted in those places where the stocks which have become diseased have been removed.

The virus of this disease is transmitted not only to rice, but to dry land rice, millet, Akimehishiba, Mehishiba, Miwahokori, and barley. Therefore, it is both necessary and difficult to eliminate the perennial weeds and grasses which grow in the hibernation areas of this insect.

END